Interactive Objects

Until now, we have assumed that the user is a passive observer. However, many of the visible objects could be interactive elements. They could be movable objects (in some cases with up to six degrees of freedom), or they could be control elements such as buttons, knobs, and sliders, or data entry text fields (name, rank, and serial number). Input of control devices could be via a keyboard, pen pad, mouse, trackball, light pen or gun, universal remote control, power glove, voice, foveal tracker, alpha wave sensor, or polygraph machine—virtually anything which can convey a response. Interactive control objects can be anywhere from very simple to extremely sophisticated. Interaction can be used in a variety of ways:

Here, see how the gun turret's range of motion is deliberately limited to prevent accidentally shooting off the rotor blades;

Try this framowitz's control panel to see how intuitive it is to operate;

Please answer the following questions. Your response will be returned by modem;

To see if and how your unit is expected to come under attack during the next few hours, click your location on this area map.

Off-Line Interactive Multi-Media

Off-line multi-media has both advantages and disadvantages compared to real-time broadcasts. It has the advantage of time-independence—the user may be completely free to browse through materials at leisure. However, broadcast provides structure and guidance that is often necessary, and does not require the physical conveyance of media for its utility.

The advent of erasable recordable optical disks combined with the described broadcast system may offer the best of both worlds. Interactive materials (e.g., courses, news, battle plans) can be downloaded and stored for later use. The real-time broadcast can then use those materials to lead the user through a study plan, a summary of news events (some of which can be explored in depth off-line if desired), or a general battle plan (the specific instructions relating to your unit to be examined off-line).

Simulation

The following definitions of "simulation" are given in one dictionary:

1. The imitative representation of the functioning of one system or process by means of the functioning of another.
2. Examination of a problem often not subject to direct experimentation by means of a simulating device.

Simulation in the context of this system is an extremely powerful concept. It provides a very inexpensive means of providing critically needed training and exercises anywhere in the world at any time that it is needed.

Properties of Objects

A software object, particularly one having a visible rendering, can be assigned properties which define its independent or interactive behavior. An example of an object having independent behavior is one that might present a particular weather scenario for a simulated battle or instrument flight. Another might be one that initially allocates 138 tanks for a simulated ground attack. An object having interactive behavior might be one that visibly destructs when adequately targeted and attacked with sufficient destructive power, or performs evasive maneuvers depending on its situation. Another type of simulation might be a test instrument which displays a voltage time-waveform when a movable test probe is placed on a simulated circuit terminal.

Local Interaction

By "local interaction" we mean simulations where, at least during the course of its primary operation, the interaction occurs totally within the self-contained or receiving device. This does not preclude evaluation or participation information being returned by a communication path at a later time. Because we are suggesting a system that primarily operates in a broadcast mode, local interaction is the expected normal mode of operation.

Remote Interaction

By "remote interaction" we mean that some type of external message passing is possible and that individuals or equipment in some other location can respond to those messages. An example might be a simulated aerial dogfight with another pilot, where the main background and conditions are set and broadcast (possibly in high-resolution) from a central location but individual airplane control response is communicated back by means of a low-bit-rate, but real time, communication path. It might also be possible for an individual participant to be mostly involved with local interaction interspersed with occasional remote interaction. This type of scenario could make very efficient use of the available resources.

Transmission

Another innovation is the transmission system which actually conveys the information from the source coder to the receiver. There are many possible specific implementations depending upon the particular application. However, many basic principles of operation remain invariant and are generally applicable.

Robust Modulation

One of the characteristics of digital transmission is that one bit looks like any other. However, if bits are repeated and enough information is retained about each bit before making a final decision as to its value, it is possible to greatly enhance the accuracy of the information. Alternatively, acceptable performance can be attained under more adverse conditions such as the weaker signal provided by a smaller antenna. Bits or multiphase symbols can be coherently combined and then conventionally demodulated, or an error correcting code can be used to further enhance performance (e.g., a convolutional code and Viterbi decoding). The latter is usually the superior-performance alternative although it sometimes suffers from not using a systematic code, i.e., information can not be recovered without error correction decoding, even if adequate signal-to-noise ratio is available. For use with a small antenna, it is possible to include both coherent bit combining and error correction coding. Design of a digital demodulator could provide for the possibility of both.

Error Correction Coding

Highly compressed video and computer software are both very vulnerable to bit errors. In the commercial field it is generally accepted that the BER (Bit Error Rate) required for compressed video is 10^{-10} or less. The convolutional coding described previously is used mainly to allow operation at lower Signal-to-Noise Ratios (SNRs). The coding gain is traded against other link budget parameters at a specified raw-channel BER, usually in the 10^{-3} to 10^{-5} range. To get the BER below 10^{-10} it is necessary to also use a reasonably good block-error-correcting code. If the input BER is reasonable (e.g., 10^{-5}) it does not take much error correction to lower the BER to the desired 10^{-10} or lower. The particular choice of code is significant to the transmission system because it will strongly influence the choice of data packet size.

Multiplexing

There are many ways of combining multiple bit streams into a single signal. However, the most commonly used, and probably the most flexible, is some form of TDM (Time Division Multiplexing). TDM most commonly divides a fixed block of time into prearranged sequential sub-blocks, each of which contains bits from a particular information source. One sub-block, sometimes as short as one bit period, usually contains frame synchronization information which provides the timing reference for locating particular data. Through prearrangement, a receiver knows the timing offset of its data from the framing reference and can extract the relevant information.

There is no reason why the signal modulation in the individual information blocks must be identical. Some can be more robust than others and be destined for disadvantaged receivers such as those having small antennas. Because transmitter power is often limited, increased bit durations, repeats, error correction redundancy, or frequency selectivity may be assigned independently for each sub-block.

Channel Buffering

Channel buffering is required for at least two reasons. One is that TDM multiplexing often handles packets of data rather than individual bits. Therefore, enough data must be accumulated to comprise an entire packet. Alternatively, if at the assigned time not enough bits are resident in the buffer, dummy bits and some message flags can be included to fill out the remainder of the block. The second reason is that data may come in bursts rather than at a steady rate. The channel buffer is used to smooth out the data rate so that a fixed-rate channel or multiplexer can handle it. Intra-frame coding of video is a prime example of the need for this type of channel buffer. Information about the fill of this buffer can be used to regulate the generation rate of video data by altering the performance evaluation criterion to emphasize either quality or data rate or some specified combination thereof.

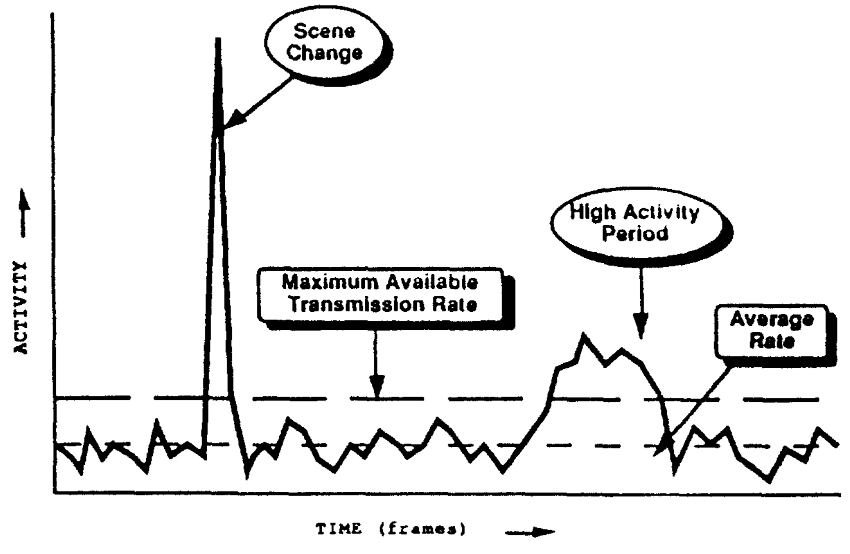

Figure ??? Variability of Data Rate

Dynamic Multiplexing

For data sources that all originate at the same location, multiplexing and channel buffering can be combined into one very efficient system. Some information must be transmitted to associate the appropriate data with each source. However, a single channel buffer can serve several sources. The advantage is that individual peak loads rarely occur in sufficient time proximity to threaten buffer overload. In those rare cases, feedback from the buffer can be used to choke back the source data by temporarily causing the source coders to operate at lower quality. Rather than thinking of this as a 0.1% occurrence of degradation, it should correctly be viewed as a 99.9% enhancement of quality compared to a system which does not share capacity. It is called "dynamic multiplexing" because the source data mix varies dynamically from frame to frame as the need demands.

Disparate Sources

The multiplexing operation usually requires that all of the multiplexed sources be co-located so that they can be combined in an orderly manner before transmission. That is not always possible because of disparate physical location of the sources. Instead, the signals may come together at a remote location such as with multiple uplinks to a geosynchronous satellite. This Time Division Multiple Access (TDMA) requires additional capabilities such the remote coordination of transmissions, compensation for timing differences due to differing in path lengths, timing guard bands to allow for switching transients, carrier and symbol sync switching transients, and dealing with gaps in the signal which can cause problems in some types of power amplifiers.

Synchronization

There are several levels of synchronization required. Basic frame synchronization provides a reliable flag which can be easily recognized during an initial signal acquisition search. Depending on the particular application, this search could range over a four dimensional space. i.e., time, frequency, azimuth, and elevation. Sometimes this is done with two types of framing sequences: one for acquisition and coarse sync, the other for fine sync. Frame sync also allows timing tracking and provides the timing reference for locating particular data in the transmitted sequence, assuming that the receiver already knows the relative relationships involved. Carrier phase acquisition and tracking can be established here also.

If disparate sources are allowed, then some type of minor sync or preamble should precede each of the individual source bursts. For each of these bursts, the receiver must either reacquire carrier phase or reestablish a demodulation phase reference. Symbol sync may also need to be quickly tweaked. Assuming that the source can also monitor the composite signal, the onus for maintaining basic timing sync can be on the source itself, thus easing the synchronization requirements of the receiver.

The proprietary design of our digital demodulator and our particular synchronization techniques will allow virtually instantaneous context synchronization response. The digital demodulator will also counteract the relatively unstable antics of some of the inexpensive local oscillators used in receiver downconverters.

Reconfiguration

In allowing disparate sources it is not likely that all sources will have identical capacity needs. Additionally, these needs may vary at different times or according to different circumstances. Assuming for the moment that such variations do not necessarily occur in a totally deterministic manner, it is necessary for the elements of the system to inter-communicate and have a method of conflict arbitration and assignment control.

Complete random access, with its inherent inefficiency, is neither required nor desirable in this system. Neither do we need to resort to complete TDMA, CSMA, slotted Aloha, or similar techniques. Instead, a single controller will assign slot ranges for each of the active sources. Enough information will be associated with the primary sync sequence to allow a receiver the determine at the instant of reception exactly where the desired information resides. Therefore a receiver may only have do demodulate primary sync and data from the desired source.

Any source can request an adjustment in its allocation by sending a message to the main controller by means of its existing allocation or through a slot allocation specifically reserved for such request. It can also use such slots for adjusting is relative timing to ensure adequate source synchronization.when given an operational slot assignment

Theoretically, this procedure could be used in the Dynamic Multiplexing scheme previously described. However, when implemented through a geosynchronous satellite, the request-to-assignment delay is excessive and would require larger channel buffers than what are economical justifiable. Of course, a group of service providers associated with one signal source (e.g., one uplink) could still be dynamically multiplexed within the fixed (but reassignable) source allocation.

Security

COMSEC

Protecting the information content from unauthorized use is a major issue for both military and commercial transmission. In the commercial case the emphasis may be on protecting the salability of information access. It could also emphasize the proprietary nature of the information such as technical/sales training before public release of a new product. The military need for protecting information access is quite obvious.

Digital transmission with hard encryption has long been recognized as the only way to get any reasonable degree of communication security. Encryption and decryption functions are now inherently inexpensive to implement. The encryption process (if implemented properly) does not reduce transmission capacity or cause any type of information degradation. Encryption algorithms are available today which are extremely secure and virtually unbreakable.

The real issue with communication security is distribution and protection of the key(s). Much can be done over the transmission system in the way of addressing individual receivers and selectively authorizing access. Alternate (possibly low data rate) communications channels can also be used to pass keys and provide an enhanced level of security. However, there are times when it is simply necessary to physically convey some type of key such as a "smart" card or solid state, encapsulated crypto ignition key (e.g., the infamous Kyk-13).

One advantage of the highly flexible system that we have described is that if a particular unit has been determined to be compromised, the entire system can be over-the-air rekeyed in a matter of seconds or minutes rather than the days required by previous systems. Multiple layers of encryption can be applied when necessary.

TRANSEC

Transmission Security is mainly used either to prevent signal detection and tracking or to prevent access denial (i.e., jamming). Often, the former is a key element of the latter. Although TRANSEC functions may not be appropriate for operation of some services through commercial satellites, the portion of the network being used in a theater of operation and especially operating at EHF could easily be anti-jam protected by frequency hopping, time shuffling, interleaving, etc. Much of this would work into the basic signalling scheme previously described. Particularly robust services could be provided by coherent bit combining or amplitude combining of MF signals. (Phase continuous synthesizers are possible today using a high-speed DDFS.)

Software

Highly Structured Data-Encapsulating Languages

There are basically only two programming languages appropriate for this system: Ada and C++. Ada has been the military's thrust for over a decade in an attempt to bring adequate functionality, real-time capability, and some level of standardization to the myriad of complex and proliferating systems. Ada is a copyrighted language with strict feature control and tight rules for compiler certification. It was hoped at one time that it would also become a commercial success, thus ensuring its viability.

Ada has its roots in Pascal and is strongly typed, highly structured, and provides for data encapsulation. It is well suited for top-down design and easily lends itself to Program Design Language (PDL) designs. It can also handle concurrency and real-time process control. It was also hoped that Ada would spur a software "standardized components" industry much like the 7400/5400 series of integrated circuits and LSI did for hardware design. There are now many producers of Ada compilers for a variety of platforms including personal computers such as DOS machines and the Macintosh.

At this time, Ada is not an object oriented language. However, object oriented extensions are starting to appear, such as Classic-ADA™ from Software Productivity Solutions, Inc. This is really a preprocessor á la AT&T's CFront (which translates C++ into standard C). Therefore, it retains full compliance and compatibility with all certified Ada compilers.

Unfortunately, while the military may have a fast-response fighting capability, it will never be accused of having a fast design-procurement-deployment cycle. By 1990, the commercial software world had started to realize the advantages of OOP and was in a full stampede toward AT&T's "C++". This language is technically an extension (or superset) of "C." The latter was originally designed as a control language and was very closely associated with the UNIX operating system. "C" has higher level functionality than assembly code but allows implementation of routines with close-to-assemble-language efficiency. It also works closely with the processor's register set. "C" imposes very little structure and allows one to do almost anything without the compiler complaining. It is a programmer's dream and a software designer's nightmare.

C++, on the other hand, is essentially a new language. It is strongly typed, encourages structured design, provides encapsulation, and supports (although it does not force) object oriented design. One advantage of C++ is that it is a standardized language and is being implemented on virtually every hardware platform. It now appears that, at least in the commercial world, C++ is the language most likely to result in standardized modules and spur a software components industry.

Object Oriented Programming

Object Oriented Programming (OOP) provides "encapsulation," encourages reuse of code by "inheritance," and allows customization by "overrides." Standardized "messages" cause actions whose implementation can be specific to particular types of objects. This "polymorphism" allows system design from the functional level without regard to the particular implementation required for a specific object. An objects can be "instantiated" (i.e., created) by either constructing it from an object class template or by "cloning" an existing object. Very complex structures of related objects can be created while keeping a very simple interface to the external world. This ability to "hide" data and functionality is very important. It is analogous to driving a car without necessarily looking inside the transmission.

OOP has been a natural for implementation of the Graphical User Interface (GUI) and for handling event-driven software. Although GUIs make systems more user-friendly, they generally make the programmer's job much more difficult. Today's GUIs can be immensely complex. If they are not implemented carefully, they can contribute to instability and reduce reliability. To combat this problem and to prevent "reinventing the wheel" for every new application, object class libraries have started to emerge. These are sets of "canned" objects, many of which are already interrelated and interconnected into a generic starting-point application which can be expanded to perform the the desired functions. The basic code is well tested and very robust. This approach would not have been possible or at least would have been very difficult without OOP. Other object class libraries are now available to support word processing, drawing, data bases, 3D graphics, and more.

The described broadcasting system will extend the OOP concept to communications systems where transmitted objects will be used to remotely control the display of information, simulate appearances and behaviors, allow real-time or off-line interaction, and possibly collect, forward or return information through other available communications paths.

Presentation and Animation Packages

There are many presentation and animation software packages available today and more will be coming on line as the market for electronic and hypermedia publications and presentations continues to grow. Drawing programs have reached a high level of sophistication and allow a full range of techniques, tools and colors. An electronic version of slides or transparencies is commonly used in live, remote, or recorded presentations. One simple technique that was quickly adopted is that of slide sequencing where, instead of presenting the entire slide, individual bulleted lines or graphic elements are added (or revealed) one at a time, resulting in a more focused and more effective presentation.

Animation is now becoming relatively easy to include in a presentation. Animated bullet charts, complete with transition effects, are as easy to do as ordinary charts. Many packages do flat cell animation and allow for importation of many other types of art objects including sequences from 3-D rendering packages. The degree of visual presentation sophistication will be determined by the particular need and the resources available (including the budget). With the personal computer tools available today it does not require a large budget or expensive equipment to produce an effective presentation. General Schwartzkopf can wow the press with his flip charts, but the rest of us need more help. This system can economically provide it.

Authoring Tools and Interactive Multimedia

There are many new types of software available in the category of authoring tools. Because of the random access capability of most electronic media, these tools normally support many types of almost instantaneous cross-linking of information, i.e., "hypertext" or "hypermedia." These tools provide the software structure to convey the information content, thus allowing the author to concentrate on the content rather than on computer programming. The user can "browse" through the information an a non-linear manner rather than the first-to-last progression typical of most printed or video taped materials. The information can be printed, graphic, animated, sound, photographic, motion video, simulation, or any number of others or combinations thereof. The source of the information can be computer memory, hard disks, floppy disks, data tapes, CD, CD ROM, CDI, video tape, laser disks, TV camera, microphone, image scanner, X-ray machine, ultra-sound, MRI, IR camera, mm-wave imager, etc.

Interactive "multi-media" (created with the authoring tools) can be used in a variety of ways: It can be "published" on laser disks for totally independent study; It can be used real-time by a lecturer to give a presentation; It can be transmitted in its entirety for associated off-line interactive use; It can be used to lead the receiving user through the materials; It can be used interactively by the lecturer to address queries sent by other means.

The military has immense documentation and training needs and has recognized the potential of multi-media publications and begun steps to incorporate such in many areas. This broadcasting system meshes perfectly with the interactive multi-media trends and provides another dimension of capability. The synergism of these technologies will provide capabilities in many areas which exceed previous capabilities by orders of magnitude.

Multimedia Broadcast Integration

To do an entire broadcast, whether real-time or recorded, will require an additional layer of software to provide segment sequencing, on-the-fly revisions, resource and time management, equipment control, an elegant user interface, and overall integration of operation. There have been several packages designed to do these functions for off-line video tape production. However, none presently exists to do the real-time integration necessary for the purely digital largely OOP-based software broadcasting needed in this system.

Possible Operational Scenarios

Field Operation and Exercises

Many types of field simulations and exercises could be done in a real staging area such as the Saudi Arabian desert. One command center could launch a simulated attack or response and send wide-band (high bit rate) data through the system to another command center and lower bit rate data to the field units. For example this would allow testing response time to an aerial, SCUD, and artillery chemical weapon attack. Simulated airplanes, missiles and other threats could be used to determine where there are weaknesses in the defense system or flaws in an attack plan.

Mission Specific Training

Short deployment response time often means that there may have been little or no time to prepare many of the troops for the physical and cultural environment of the host or enemy countries. Time spent waiting for marching orders could be used to learn key words and phrases of one or more of the local languages. Training could be provided on particular weaponry and tactics commonly used by the enemy. All of this could be done from the safety of a fox hole or bunker with a light-weight portable receiver.

Special Forces

Using a small portable unit, special forces behind enemy lines could receive high-resolution reconnaissance images, retaining only that data relevant to their mission. For example, images could be collected from satellites, aircraft, or reconnaissance drones and then be automatically grid indexed, encrypted, and transmitted through this system. An integrated GPS receiver would provide the user with the exact location. The image receiver processor would extract and store the applicable grid sectors. Relatively large areas could be acquired and stored at lower resolution and specific selected sectors at high resolution. The user would be able to indicate on the larger area image those areas for which high-resolution image retention is desired. The transmitted images could indicate areas that have been designated for further ground investigation. The user would be able to zoom-in on areas of mission interest or sources of immanent danger. One of the advantages of this approach is that at no time is any transmission from the user required which could compromise his presence or location.

Home/Office Military Training

In many areas military training services could be offered on high-power commercial satellites where reception could be through small antennas at individual homes or offices. This could be particularly attractive for Reserves, National Guard, and even career personnel. Such high-power satellites will shortly be available in North America, Europe, and Asia. Interactive multi-media training programs could be provided, covering many aspects the military and a variety of situations and equipment types. By either using the built-in computer capability of the basic receiver, or by using a separate personal computer, realistic simulations could be included, based on broadcast OOP techniques.

Basic familiarity with equipment could be attained and operational procedures could be learned before ever seeing or touching actual equipment or systems. Even flight simulation on personal computers has become realistic enough that it has become acceptable to qualify for instrument time for private pilots and others. As high resolution systems become common, this type of simulation could conceivably become inexpensive but effective for military flight simulator time. The mission and various flight and warfare situations could be transmitted to the home/office receiver. Trainee participation verification and performance evaluation could be modemed back to the trainer.

A major advantage of this approach to training is that it could easily be continued after a disruption such as a relocation.

General Education

The system is capable of handling a large number of general educational courses in addition to its those for direct military training. Course lectures can be offered along with interactive multimedia and even simulations of laboratory equipment and lab experiments, e.g., physics, chemistry, biology, medicine, engineering, etc. An entire spectrum could be offered, from K-12 for the serviceman's family, to graduate courses and adult education. More specialized courses in such areas as manufacturing technologies could also be offered. Courses normally not intended for military use could be piped to military installations all over the world.

Direct Briefings

This system would allow the generals and others to directly address the troops using both audio and video. News programs and even entertainment TV could be brought in and adjusted to the available (and of course, preemptable) bit rate.

Hospitals

Military hospitals could both pose as users of the system and serve as information and broadcast originators. The potential for offering medical training programs and upgrading the quality of medical care is immense. This is also an ideal application area for high resolution image transmission and display technology. Images could be shared over a worldwide network for training and consultation. Specialists' opinions from hospitals in the U.S. could be obtained in the battlefield. This could also a valuable when treating opposing soldiers and civilian populations for whom evacuation to U.S. hospitals might not be possible or desirable, such as the situation with the Iraqis and Kurds.

Field Service Maintenance

As systems become more complex and expensive, the problem of field service maintenance and sufficiently trained personnel becomes more and more acute. When troops are rapidly mobilized and placed into an alien environment such as happened in the Persian Gulf crises, there is not always a one-to-one match between available equipment and trained equipment maintenance technicians. Also, during the months of buildup, there were a lot of very bored troops sitting in the sand. This could have been an ideal time to use the described system for maintenance training and for customizing that training for coping with the particular environment. (Hey guys, you aren't supposed to wear the panty hose, use it to keep the sand out of your equipment!)

What Needs to be Done

The following is a partial list of tasks to complete the system design. Task descriptions and project planning, based on these items, will be further developed when warranted.

Systems
- Multiplex Format
- Signal Structure
- Traffic Characterization and Statistical Analysis
- Flexible-Demod Parameter-Performance Simulation
- Transmission Data Management and Multiplexing
- Select, Simulate, and Evaluate Compression Algorithms
- Determine Drawing Primitive Set
- Demonstration of Interfaces and Simulation of Operation
- Transmission Operating System
- Develop and Demonstrate Object Transmission Capability
- Receiver Partitioning and System Design
- Overall System Design and "A" level Specification
- Receiver "B" level Hardware Specifications
- Receiver "B" level Software Specifications
- Transmission Link Budgets
- Explore Opportunities for Return Links

Receiver Hardware
- Antennas, LNBs, Downconversion
- Synthesizers, TRANSEC
- Tuner, IF, and A/D
- Flexible Digital Demodulator
- Synchronization
- Error Correction Decoding
- Service Selection/Decryption
- Video Decompression
- Audio
- Graphics Processor
- Main Controller Processor
- Interfaces to Other Hardware
- LSI Development
- Mechanical, Thermal, and Power Design
- Receiver "C" level Hardware Specifications

Receiver Software
- Graphical Interface
- Controller
- Memory Management
- Dynamic Late Binding of Objects
- Object Life Management
- Integration with Other Equipment and Systems
- Multi-Media Source Materials for Tests and Demos
- Interface Def. for Other Computers and Displays
- Receiver "C" level Software Specifications

Military Computer Systems Software

Transmitter Hardware

Transmitter Software

Conclusion

The described work will allow military organizations to leverage the impact of its high resolution systems endeavors through a digital broadcast satellite signal distribution system. The program will have major emphasis on allowing capabilities for interactive uses and simulations using object oriented programming techniques and broadcast simulation objects. Access of military personnel to conventional educational programs, regardless of location, could also be included.

Appendix A: Key Personnel

G. Gordon Apple, PhD

Dr. Apple was principal investigator and project manager for a joint effort with CBS Television to develop data compression for HDTV using digital transmission via Direct Broadcast Satellites in 1981-82. He was assistant Program Manager for VHSIC (Very High Speed Integrated Circuit) ground terminals for the MILSTAR satellite system. He was then principal investigator for IRAD programs for small, light-weight military satellite terminals.

In recent years Dr. Apple has concentrated on conceptual development, system design, and promotion of digital transmission for DBS television, HDTV, educational services , and others. He has promoted personal computers for receiving (digitally) broadcast services directly using a flexible combination of data compression, file transfer and control, and transmission of drawing primitives and persistent objects. He is actively engaged in extending the concept of "object oriented programming" (OOP) across boundaries between diverse processors and in the use of OOP in a broadcast environment. He is also a certified developer for Apple Computer.

At Purdue, Dr. Apple developed a transform-coding digital filter for NASA. He then worked at Bell Labs on digital-interframe-coding video-compression for PicturePhone® transmission. At North Electric his group developed transmission, synchronization and multiplexing systems for a digital telephone switching system. He then was Director of Engineering for Automation Products Company in Austin, Texas. At TRW, Dr. Apple was a project manager for digital communication system projects including satellites, modems, and data compression systems. He was a system engineer on Space Shuttle communications and other satellite programs including an Intelsat VII proposal. He was the system engineer for projects that developed a television satellite transmission scrambling system and which developed a highly flexible fiber-optic transmission system.

Dr. Apple received his BSEE degree from the University of Arkansas in 1966 and an MSEE and PhD from Purdue in 1967 and 1970 respectively. He has over 25 years experience in digital communications and has patents in the fields of error correction coding, digital transmission, synchronization, and video data compression. Dr. Apple is a Senior Member of IEEE, a member of Sigma Xi (research society), Eta Kappa Nu, Tau Beta Pi, Pi Mu Epsilon, and SMPTE. He is a Registered Prof. Engineer and an instrument rated pilot.

Compuserve: 71311,2544 AppleLink: D4887

The Personal Digital Satellite Ground Station

for the

Business and Consumer Electronics Market

Presented to TRW

April 11, 1991

Donald K. Dement (301-858-5702)
G. Gordon Apple (213-540-6532)

ACE Concept and Overview

- **Because**
  - Microcomputers and TV technology are converging rapidly
  - Digital TV signals delivered via DBS and/or other means create an era of rapid change
- **ACE targets**
  - A fully integrated digital-to-analog personal satellite ground station and conversion device for use with TV, microcomputers, and other devices
  - Provide turnkey technology solution for DBS systems in US and abroad
  - Incorporate receiver design elements into future, fully-digital TV

ACE Designed Products and Services

- Integrated Open-Architecture Receiver Design
- Digital Demodulator Design
- Operating Systems for Transmission and Reception
- Local Graphic and Animation Primitives
- Source and Transmission Compression Algorithms
- Broadcast System Design and Engineering Management

How Has DBS Changed, 1982-1991 ?

- Cost per delivered channel of full motion color video service has dropped by a factor of 20
- Enough programming available now, more will become available
- Demand for a broad array of video and other services is increasing
- Digital encoding significantly increases program security
- Cost of ground equipment in mass market "consumer electronic" range

DBS Market Demand

- There are 94 million TV households in the US, growing at approximately one million per year
- 40 million of these have no cable services
- Surveys consistently report 9% of cable customers will switch to DBS in the first year of its availability; additional 25% likely to switch over 5 years
- Many rural areas will never have cable services
- Approximately 3 million C-band dish users -- add-on or switch to DBS
- DBS will provide basic services for less than average cable fees
- DBS will provide classes of services not available today
- Every DBS subscriber will need a receiver

Advantages of DBS Over Cable

- Lower capital costs for digital delivery to all of the US
- Lower operating costs
- Greater capacity than existing analog cable systems
- Ability to deliver new types of services
- Greater program security than analog systems
- Diversifies source of multichannel programming delivery
- Universally available, often higher quality picture
- More efficient distribution of eventual HDTV signal

HDTV and Computers

- All proposed HDTV systems require at least partial digital transmission.
- Digital DBS can easily be made compatible with any proposed HDTV system.
- All proposed HDTV systems require large digital memories, a substantial digital signal processing, and sophisticated programmable control.
- Personal computers are rapidly moving into desk-top video, high-resolution displays, signal processors, and television interfaces.
- The technology is the same.

Capacity of One Transponder

- 30 megabits per second
- One classroom lecture uses 250 kilobits per second

120 such lectures are possible on one transponder